EFFECTS OF CHROMIUM POWDER MIXED IN ELECTRICAL DISCHARGE MACHINING OF AISI D2 HARDENED STEELS

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This research is dedicated to my family especially to my father, Encik Idris bin Jusoh and my late mother, Puan Kamariyah Hasan, thank you for the support, encouragement and spiritual, also thanks to my supervisor, Assoc. Prof. Dr. Mohd Amri Bin Lajis for the guidance, opinions and advices.

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ABSTRACT

Nowadays, electrical discharge machining (EDM) is the non-conventional method that has been used extensively in machining hard material that is commonly used in mold and die industry but the limitations of EDM will cause lower productivity and poor surface quality. EDM becomes most apparent by using powder metallurgy electrode together with chromium (Cr) powder suspension into the dielectric fluid which has led to the increasing of productivity and good quality performance and characteristics. Therefore, by combining of both EDM parameters and machining conditions by incorporating with specific magnetic system plus integrated with existing filter system, it is highly expected that the machining speed can be enhanced. However, there are difficulties to determine the best combination of these machining parameters in order to increase the material removal rate (MRR) and at the same time to reduce the electrode wear rate (EWR) with the acceptable surface integrity. This research emphasizes the studies of Cr powder mixed in EDM machining of AISI D2 hardened steel using copper tungsten electrode which has been done successfully. Data were analysed using design of three factors at a time consisted of peak current (I_p), pulse-on (P_{on}) and powder concentration(C). Discussions were made on the responses such as MRR, EWR, Surface Roughness (R_a), surface morphology, recast layer (R_L) and microhardness (MH) on the selected samples from the same machining conditions. Results have proved that I_p was the most significant parameter which has influenced the machining responses on Cr powder mixed EDM of AISI D2. It is also found that proper powder concentration of 2gram/litre enhanced the machining efficiency particularly in MRR. Furthermore, introduction of proper addition of Cr powder in the dielectric also decreased R_a and R_L thickness. The EWR increased as the peak current increased, but inversely with pulse-on. In general, the possibility of EDM process for machining AISI D2 tool steel by incorporating Cr powder mixed in the dielectric is acceptable and the entire objectives were successfully proven.

ABSTRAK

Pada masa kini, mesin nyahcas elektrik (EDM) adalah satu kaedah tidak-konvensional yang telah digunakan secara meluas di dalam pemesinan bahan keras yang lazimnya digunakan dalam industri acuan tetapi kekurangan yang ada pada EDM akan menyebabkan pengeluaran produktiviti yang rendah dan kualiti permukaan pemesinan yang tidak baik. EDM akan menjadi lebih baik dengan menggunakan elektrod jenis serbuk metalurgi bersama-sama dengan campuran serbuk kromium (Cr) ke dalam cecair dielektrik yang boleh meningkatkan produktiviti dan menghasilkan ciri-ciri pemesinan yang berkualiti. Oleh yang demikian, dengan gabungan kedua-dua parameter EDM tersebut ditambah pula dengan sistem magnet yang menggantikan penapis sedia ada dijangka meningkatkan kelajuan pemesinan. Walau bagaimanapun, terdapat kesukaran untuk menentukan kombinasi parameter yang paling baik untuk meningkatkan kadar pembuangan bahan (MRR) dan pada masa yang sama mengurangkan kadar haus elektrod (EWR) dengan integriti permukaan yang boleh diterima. Kajian campuran serbuk Cr dalam cecair dielektrik diuji dengan keluli keras AISI D2 sebagai bahan kerja dan menggunakan kuprum tugsten sebagai elektrod telah dilakukan dengan jayanya. Data akan dianalisis menggunakan reka bentuk daripada tiga faktor iaitu arus puncak(I_p), kadar denyutan(P_{on}) dan kepekatan campuran(C). Tindak balas seperti MRR, EWR, kekasaran permukaan bahan (R_a), morfologi, lapisan kesan pemanasan haba (R_L) dan mikrokeras hasil dari sampel yang dipilih dari keadaan pemesinan sama akan dibincangkan. Keputusan menunjukkan bahawa I_p adalah parameter yang paling berkesan mempengaruhi pemesinan. Ia juga mendapati bahawa tambahan serbuk Cr akan membantu meningkatkan kecekapan pemesinan terutamanya dalam keputusan MRR. Campuran serbuk Cr dengan kuantiti optimum sebanyak 2gram/liter ke dalam dielektrik akan mengurangkan R_a dan R_L. Selain itu, EWR meningkat kerana peningkatan arus tetapi menurun jika masa denyutan ditambah. Secara umumnya, sesuatu proses EDM untuk pemesinan keluli AISI D2 dengan serbuk Cr dicampur dalam dielektrik boleh diterima dan keseluruhan objektif telah terbukti.

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LIST OF ABBREVIATIONS AND SYMBOLS

Al	-	Aluminium
AISI	-	American Iron and Steel Institute
C	-	Powder concentration
CNT	-	Carbon nano tube
Cr	-	Chromium
CV	-	Control valve
CuW	-	Copper tungsten
EDM	-	Electrical discharge machining
EWR	-	Electrode wear rate
FPGA	-	Field-programmable get array
HAZ	-	Heat affective zone
HRC	-	Hardness Rockwell unit for steel
I_p	-	Discharge current
MRR	-	Material removal rate
PMEDM	-	Powder mixed dielectric electrical discharge machining
P_{on}	-	Pulse duration
PLC	-	Programmable logic controller
PM	-	Powder metallurgy
SEM	-	Scanning electron microscopy
SA	-	Surface area
SI	-	Surface integrity
SiC	-	Silicon carbide
TELCO	-	Tellurium copper
R_a	-	Surface roughness
R_L	-	Recast layer

t_m	-	Machining times
W_a	-	Weight of workpiece after machining
W_b	-	Weight of workpiece before machining

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CHAPTER I

INTRODUCTION

1.1 Overview

Following the technology of manufacturing today, machining process is dealing with challenges from the marketing demand that needed to requires the use of advanced materials such as composite, super alloys, and hardened steels that are so hard to be machined. The high speed machine that can produce good surface integrity and precise cutting with less tool wear, are among the criteria to use in the advance technology, i.e. aerospace, automotive and medical material. Since it is impossible to use conventional machining of hard material, non-conventional machining such as electrical discharge machining (EDM) is one of the ideal techniques in dealing with these materials including hardened steel.

EDM is generally known as a 'vertical', 'ram' or 'sinker' electrical discharge machining that has been used in the industry over fifty years ago. According to the current world developments, EDM has also increased technology that enables the EDM to produce superficial, thin and compact mechanical elements that are used by the advanced manufacturer. The power supply on a previously effective EDM has improved according to the changes in electric and electronic fields. It is capable to produce more power efficiently, generate various types of waves and high frequency. Due to the

existence of rapidly growing control systems, EDM is suitable for producing work that requires a high level of accuracy. Most of EDM use computer numerically method (CNC) as their programming to communicate with human to improve the machining process.

EDM is a machine that can provide many benefits for high accuracy and precision of machining process. It requires further research to produce a more realistic EDM. Numerous researchers have optimized the process variable to improve the machining workpiece characteristics such as by increasing the material removal rate due to increase in machining speed, increasing the tool life and obtain the best surface integrity. Some of the researchers modified the EDM system to fulfill the requirement global trend of machining process. Figure 1.1 shows some of the research area in EDM.

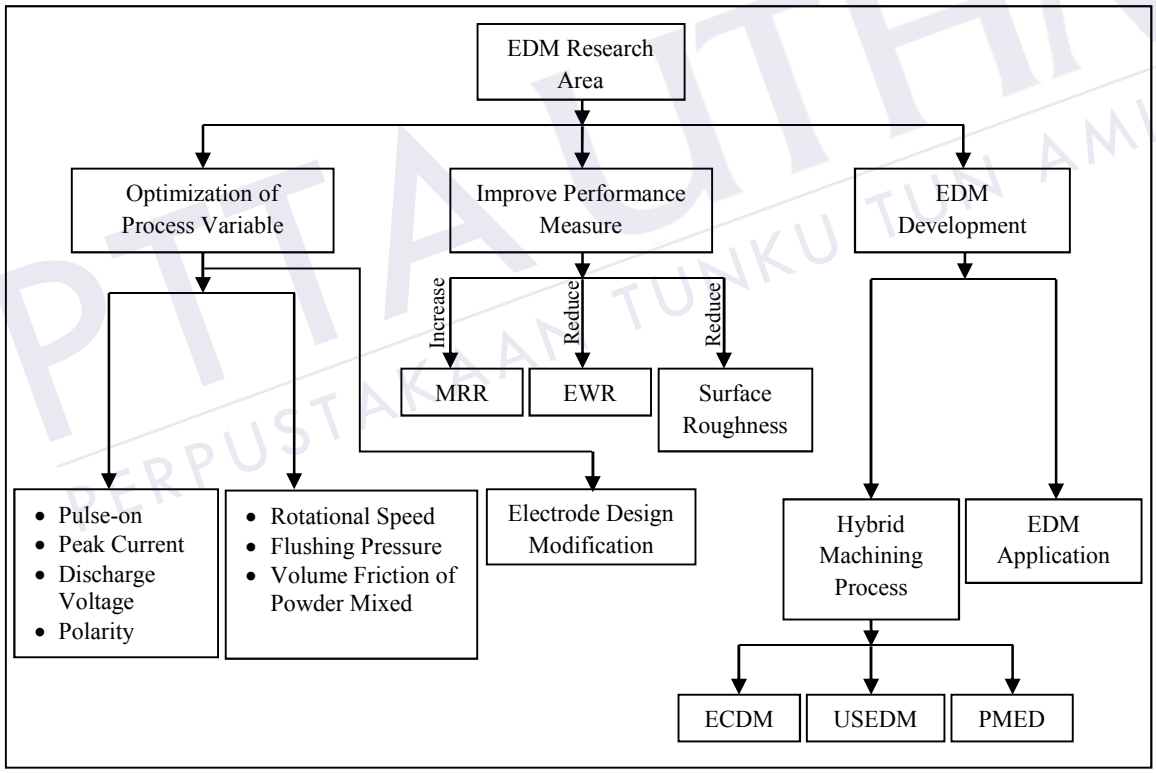

Figure 1.1: Classification of EDM research (Pandey and Singh, 2010)

High potential of EDM can help to improve productivity in the industry. Productivity is one of the important elements in the industry today. Higher productivity can lead to improved industry performance such as lower average costs, higher profits, higher

wages and improved competitiveness and trade performance. Hence, to fulfill this demand, the machines in the industry must have a high speed productivity including EDM.

1.2 Background of Study

Electrical discharge machining (EDM) is the non-conventional method that has been used extensively in the machining process of hard material that is commonly used in mold and die industry. The basic process of EDM is to remove metal through the action of an electrical discharge energy and high current intensity between the tool (electrode) and the workpiece without physical cutting force. This is one of the advance methods to replace traditional machine method that able to machine difficult-to-cut or hard materials such as titanium, inconel and hardened steel. It can be successfully employed to electrically conductive machine parts regardless of their hardness and toughness. In spite of remarkable process capabilities, limitations such as low volumetric material removal and poor surface quality are associated with EDM (Kansal et al, 2007).

Limitation of EDM will cause lower productivity, which is due to low cutting speed. In that case, researchers of EDM explored a new method to improve the sparking efficiency phenomenon including some modification of experimental concepts and their existing system. The researchers needed to consider the machining process condition and parameters such as discharge voltage, peak current, pulse-on, flushing and dielectric medium before executing the new method of the machining process. To date, most of the studies in EDM have undergone the normal effect of machining process condition which applies low level of machining parameters. Yet, few studies have been implemented in greater current and long pulse-on and at the same time to maintain the EDM machining stability and efficiency to obtain the best material removal rate (MRR), lower electrode wear rate (EWR) and the good performance of the workpiece surface

integrity. Therefore, there is a keen interest to look forward into this new phenomena in EDM machining and hence for greater productivity.

Nowadays, research becomes most apparent by using powder metallurgy electrode together with powder suspension into the dielectric fluid which has increased the productivity, and good quality performance and characteristics. Therefore, by using a combination of both EDM parameters and machining process conditions, and incorporating with the specific magnetic system plus integrated with the existing filter system, it is highly expected that this combination can enhance the machining speed. The filter system integrated with magnetic force is used to separate debris or contaminants from dielectric fluid and hence the efficiency of spark erosion becomes more stable and easy to cut the materials. In order to realize the full potential of new setting of EDM machining by incorporating magnetic and pump system, the new dielectric tank was developed which was integrated with a continuous circulation system.

Many studies have been applied through this process in several types of materials, but lack of work has been carried out to incorporate powder mixed in the EDM machining of AISI D2 hardened steels. It is also found that a comprehensive study in EDM machining of AISI D2 is still scarce. New machining data on the EDM of AISI D2 serves a great significance and could be further exploited especially for hole making operation. Further research on powder mixed EDM machining mechanism and its characteristics of this kind of material is expected to give better rate and efficiency of the machining process. This project was undertaken to study the effect of machining process conditions and incorporated with powder mixed in EDM machining of AISI D2 hardened steels and by employing advanced powder metallurgy electrode of copper tungsten (CuW).

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